and cross-talk channels, can be written as:

$$\mathbf{S}(f) = \mathbf{R}(f)\mathbf{H}(f) \cdot \mathbf{G}(f) \qquad \text{(equation 1)}$$

where ***R(f)***, ***H(f)*** and ***G(f)*** are all *N x N* matrices representing the receive filters, the channels, and the transmit filters, respectively. For purposes of simplicity, the transmit filter and receive filter for each channel are assumed to be isolated from the transmit filter and receive filter of other channels. Hence, both ***R(f)*** and **G**(*f*) are diagonal matrices. Assuming that transmit filters are identical for all channels, and that **G**(*f*) is reduced to a scalar G(*f*), equation 1 can be expressed as:

$$\mathbf{S}(f) = \mathbf{R}(f)\begin{bmatrix} H_{11}(f) & H_{12}(f) & \cdots & H_{1N}(f) \\ H_{21}(f) & H_{22}(f) & \cdots & H_{2N}(f) \\ \vdots & \vdots & \ddots & \vdots \\ H_{N1}(f) & H_{N2}(f) & \cdots & H_{NN}(\mathrm{f}) \end{bmatrix} . \mathrm{G}(f) \qquad \text{(equation 2)}$$

where $H_{ii}(f)$ represents the direct transfer functions for the *i*th communication link or user, and $H_{ij}(f), i \neq j$, represents the cross-talk transfer functions between the transmitter of user *j* and the receiver of user *i*.

Compensating for the cross-talk. a matrix **P**(*f*) directed as a pre-coding matrix is introduced and given as:

$$\mathbf{P}(f) = \begin{bmatrix} 1 & P_{12}(f) & \cdots & P_{1N}(f) \\ P_{21}(f) & 1 & \cdots & P_{2N}(f) \\ \vdots & \vdots & \ddots & \vdots \\ P_{N1}(f) & P_{N2}(\mathrm{f}) & \cdots & 1 \end{bmatrix} \qquad \text{(equation 3)}$$

such that

$$\begin{aligned} \mathbf{S}(f) &= \mathbf{R}(f)\mathbf{H}(f) \cdot [\mathrm{G}(f)\mathbf{P}(f)] \\ &= \mathbf{R}(f)\mathbf{H}(f)\boldsymbol{P}(f) \cdot G(f) \end{aligned}$$

$$= \mathbf{R}(f)\begin{bmatrix} K_1(f) & 0 & \cdots & 0 \\ 0 & K_2(f) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & K_N(f) \end{bmatrix} \cdot G(f) \qquad \text{(equation 4)}$$

where

$$\begin{bmatrix} K_1(f) & 0 & \cdots & 0 \\ 0 & K_2(f) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & K_N(f) \end{bmatrix} = \mathbf{H}(f)P(f) \qquad \text{(equation 5)}$$

Since ***R(f)*** is also a diagonal matrix, the overall system transfer function corresponds to a diagonal matrix. Thus, the introduction of matrix **P**(f) completely eliminates the effect of far-end cross-talk.

For example, in a system of two-users, ***P(f)*** is found by solving the following equation:

$$\begin{bmatrix} 1 & P_{12}(f) \\ P_{21}(f) & 1 \end{bmatrix} \cdot \begin{bmatrix} H_{11}(f) & H_{12}(f) \\ H_{21}(f) & H_{22}(f) \end{bmatrix} = \begin{bmatrix} K_1(f) & 0 \\ 0 & K_2(f) \end{bmatrix} \qquad \text{(equation 6)}$$

or

$$\left\{ \begin{aligned} & H_{12}(f) + P_{12}(f)H_{22}(f) = 0 \\ & P_{21}(f)H_{11}(\mathrm{f}) + H_{21}(f) = 0 \end{aligned} \right. \Rightarrow \left\{ \begin{aligned} & P_{12}(f) = -\frac{H_{12}(f)}{H_{22}(\mathrm{f})} \\ & P_{21}(f) = -\frac{H_{11}(f)}{H_{11}(f)} \end{aligned} \right. \qquad \text{(equation 7)}$$

In an *N*-user system, a $N^2 - N$ equation can be constructed to solve the $N^2 - N$ transfer functions of the **P***(f)* matrix. Therefore, it is always possible to find **P***(f)*, from **H***(f)* as long as **H***(f)* is non-singular. In most real-world systems however, the transfer functions **H***(f)* are either unknown, or unpractical to obtain. A practical means of obtaining a matrix **P***(f)* that satisfies Eq. (5) is to use the iterative approach described below with respect

to FIG. 3.

FIG. 3 depicts an illustrative example of interference between communication channels such as those depicted in the of the communication system of FIG. 1. Specifically, FIG. 3 depicts a functional representation of two communication channels in which interference is imparted from at least one channel to the other. A first communication channel i comprises a pre-coder function 310_i, a summer function 320_i, a transmit filter function 330_i, a first channel impairment function 340_i, a second channel impairment function 345_i, a second summer 350_i, a received filter function 360_i. Similarly, the second channel *j* comprises comprises a pre-coder function 310_j, a summer function 320_j, a transmit filter function 330_j, a first channel impairment function 340_j, a second channel impairment function 345_j, a second summer 350_j, a received filter function 360_j.

Each of the channels *i* and *j* receive a respective transmit CAP signal or symbol stream, denoted as $a^{(i)}(n)$ and $a^{(j)}(n)$, respectively. Each received transmit CAP symbol stream is coupled to the respective pre-coder function 310 and a first input of the summer function 320. The output of each pre-coder function 310 is coupled to a second input of the summer function of the opposite channel. That is, the output of decoder function 310_i is coupled to a second input of summer function 320_j, while the output of pre-coder function 310_j is coupled to a second input of summer function 320_i. The output of each of the first summer functions 320 is coupled to the respective transmit filter function 330. The outputs of the respective transmit filter functions 330 are coupled to respective inputs of respective channel impairment functions 340 and 345. The output of respective channel impairment functions 340 are coupled to first inputs of respective second summer functions 350. The output of channel impairment function 345_i is coupled to a second input of second summer function 350_j. The output of second channel impairment function 345_j is coupled to a second input of second summer function 350_i. The output of the second summer functions 350 is coupled to channel respective inputs of receiver functions 360. The output of the respective